HAYNES International

HIGH-TEMPERATURE ALLOYS

HAYNES® 282® ALLOY

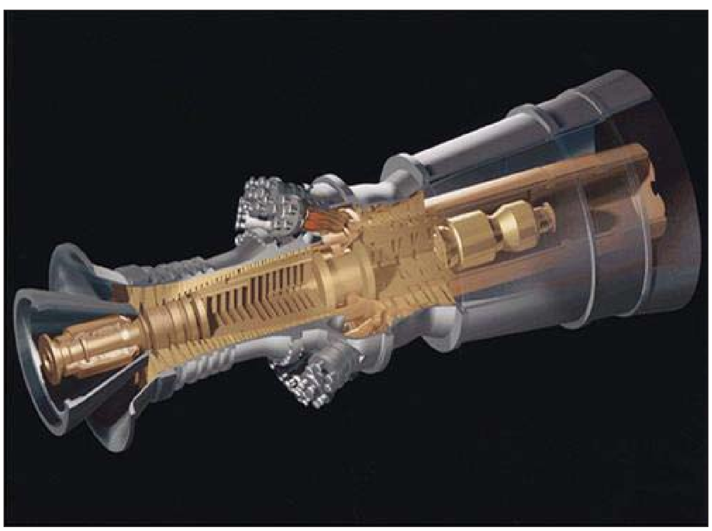
A new, wrought, age-hardenable, nickel superalloy designed for improved creep strength, weldability, and fabricability.

Contents

H-3173

TYPICAL APPLICATIONS

HAYNES® 282® alloy is designed for applications in engines for aircraft.



HAYNES® 282® alloy is designed for the transition sections and other hot-gas-path components in land-based gas turbines.

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PRINCIPAL FEATURES

Excellent High Temperature Strength

HAYNES® 282® alloy is a new, wrought, gamma-prime strengthened superalloy developed for high temperature structural applications, especially those in aero and land-based gas turbine engines. It possesses a unique combination of creep strength, thermal stability, weldability, and fabricability not found in currently available commercial alloys. The new alloy has excellent creep strength in the temperature range of 1200 to 1700°F (649 to 927°C), surpassing that of Waspaloy alloy, and approaching that of R-41 alloy.

Easily Fabricated

This high level of creep strength in HAYNES 282 alloy has been attained at a relatively low volume fraction of the strengthening gamma-prime phase, resulting in outstanding resistance to strain-age cracking (normally a problem with superalloys in this creep strength range). Additionally, slow gamma-prime precipitation kinetics allow for the alloy to have excellent ductility in the as-annealed condition. Consequently, HAYNES 282 alloy exhibits superior weldability and fabricability.

Product Forms

HAYNES 282 alloy is designed for use in the form of plate, sheet, strip, foil, billet, bar, wire welding products, pipe, and tubing.

Heat Treatment

HAYNES 282 alloy is provided in the solution-annealed condition, in which it is readily formable. The typical solution-annealing temperature is in the range of 2050 to 2100°F (1121 to 1149°C). After component fabrication, a two-step age hardening treatment is required to put the alloy into the high-strength condition. The treatment includes 1850°F (1010°C) / 2 hours / AC (air cool) + 1450°F (788°C) / 8 hours / AC.

Applications

The features of HAYNES 282 alloy make it suitable for critical gas turbine applications, such as sheet fabrications, seamless and flash butt-welded rings, and cases found in compressor, combustor, and turbine sections. In augmented aircraft gas turbines, the new alloy will be useful for exhaust and nozzle components. In land-based gas turbines, HAYNES 282 alloy is a good candidate for transition sections and other hot-gas-path components.

Nominal Chemical Composition, Weight %

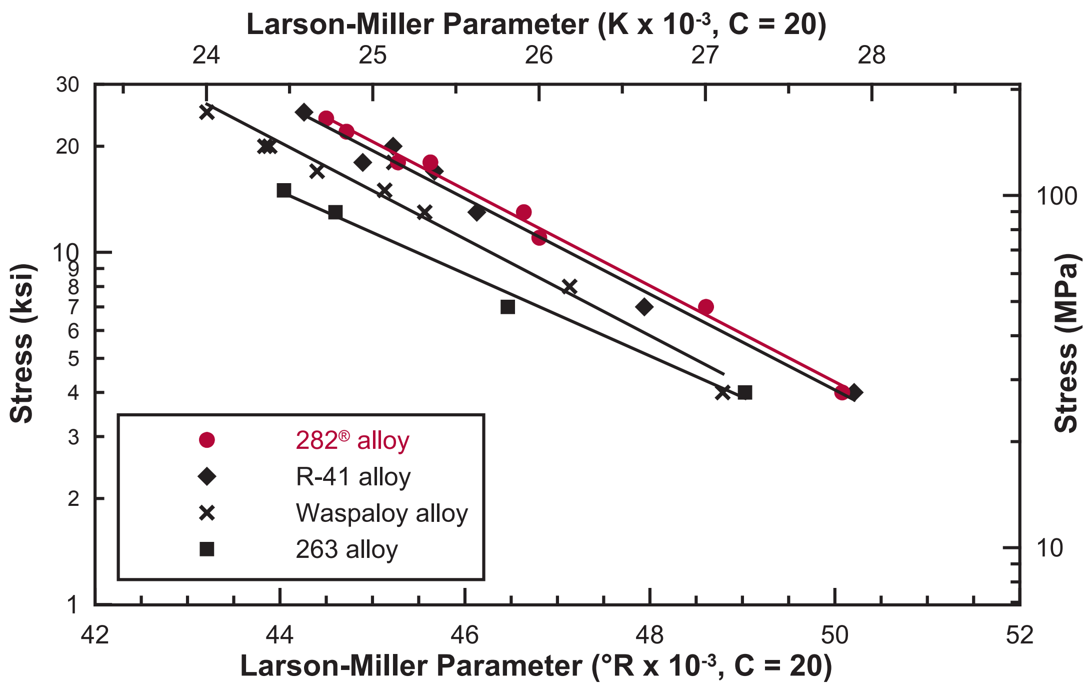
Ni	Cr	Co	Mo	Ti	Al	Fe	Mn	Si	C	B
57**	20	10	8.5	2.1	1.5	1.5*	0.3*	0.15*	0.06	0.005

* Maximum ** Nickel as balance

CREEP AND STRESS-RUPTURE STRENGTH

HAYNES 282 alloy possesses exceptional creep strength in the temperature range 1200-1700°F (649-927°C). For example, it has superior strength to 263 alloy at all temperatures in this range in terms of both 1% creep and rupture. Despite the exceptional fabricability of 282 alloy, it compares well to less fabricable alloys designed for high creep strength. For example, its rupture strength is equivalent to the well-known, but less fabricable, Waspaloy alloy at the lower temperatures in this range and actually has a distinct advantage at the higher end of the temperature range. In terms of 1% creep strength, 282 alloy is superior to Waspaloy alloy across the entire temperature range. At temperatures of 1500-1700°F (816-927°C), 282 alloy has creep strength equivalent to even that of R-41 alloy, an alloy designed for excellent creep strength, but notorious for poor fabricability.

Creep Strength of Various Superalloys in the Temperature Range 1500-1700°F (816-927°C) (Sheet Products)



Comparative Creep-Rupture Properties of Gamma-Prime Strengthened Alloys* (Sheet)

Property	Test Temperature °F	Test Temperature °C	263 Alloy	R-41 Alloy	Waspaloy Alloy	282® Alloy
Stress-to-Produce 1% Creep in 100 h ksi (MPa)	1200	649	75 (517)	105 (724)	81 (558)	–
	1300	704	54 (372)	75 (517)	63 (434)	72 (496)
	1400	760	37 (255)	53 (365)	41 (283)	48 (331)
	1500	816	22 (152)	32 (221)	25 (172)	32 (221)
	1600	871	11 (76)	17 (117)	15 (103)	18 (124)
	1700	927	6 (41)	8 (55)	6 (41)	9 (62)
Stress-to-Produce 1% Creep in 1000 h ksi (MPa)	1200	649	58 (400)	84 (579)	67 (462)	79 (545)
	1300	704	41 (283)	59 (407)	46 (317)	53 (365)
	1400	760	25 (172)	34 (234)	28 (193)	35 (241)
	1500	816	12 (83)	18 (124)	16 (110)	21 (145)
	1600	871	6 (41)	9 (62)	7 (48)	10 (69)
	1700	927	3 (21)	5 (34)	3 (21)	5 (34)
Stress-to-Produce Rupture in 100 h ksi (MPa)	1200	649	77 (531)	110 (758)	92 (634)	–
	1300	704	60 (414)	85 (586)	75 (517)	75 (517)
	1400	760	42 (290)	63 (434)	53 (365)	56 (386)
	1500	816	25 (172)	39 (269)	32 (221)	37 (255)
	1600	871	14 (97)	23 (159)	19 (131)	22 (152)
	1700	927	7 (48)	13 (90)	10 (69)	12 (83)
Stress-to-Produce Rupture in 1000 h ksi (MPa)	1200	649	64 (441)	90 (621)	80 (552)	80 (552)
	1300	704	45 (310)	68 (469)	58 (400)	56 (386)
	1400	760	28 (193)	43 (296)	36 (248)	38 (262)
	1500	816	15 (103)	24 (165)	20 (138)	23 (159)
	1600	871	7 (48)	13 (90)	7 (48)	12 (83)
	1700	927	4 (28)	7 (48)	3 (21)	6 (41)

*Age-hardened (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy : 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

Solution Annealed* + Age Hardened** 282® Sheet

Test Temperature °F	Test Temperature °C	Creep	Approximate Initial Stress, ksi (MPa) To Produce Specified Creep in: 100 Hours	1,000 Hours
1200	649	0.5 %	–	78 (538)
		1 %	–	79 (545)
		Rupture	–	80 (552)
1300	704	0.5 %	70 (483)	51 (352)
		1 %	72 (496)	53 (365)
		Rupture	75 (517)	56 (386)
1400	760	0.5 %	46 (317)	33 (228)
		1 %	48 (331)	35 (241)
		Rupture	56 (386)	38 (262)
1500	816	0.5 %	30 (207)	18 (124)
		1 %	32 (221)	21 (145)
		Rupture	37 (225)	23 (159)
1600	871	0.5 %	17 (117)	9.0 (62)
		1 %	18 (124)	10 (69)
		Rupture	22 (152)	12 (83)
1700	927	0.5 %	8.3 (57)	4.2 (29)
		1 %	9.0 (62)	5.0 (34)
		Rupture	12 (83)	6.0 (41)
1800	982	0.5 %	3.6 (25)	–
		1 %	4.2 (29)	1.8 (12)
		Rupture	5.5 (38)	2.5 (17)

*2100°F (1149°C)
**1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

Solution Annealed* + Age Hardened** 282® Plate

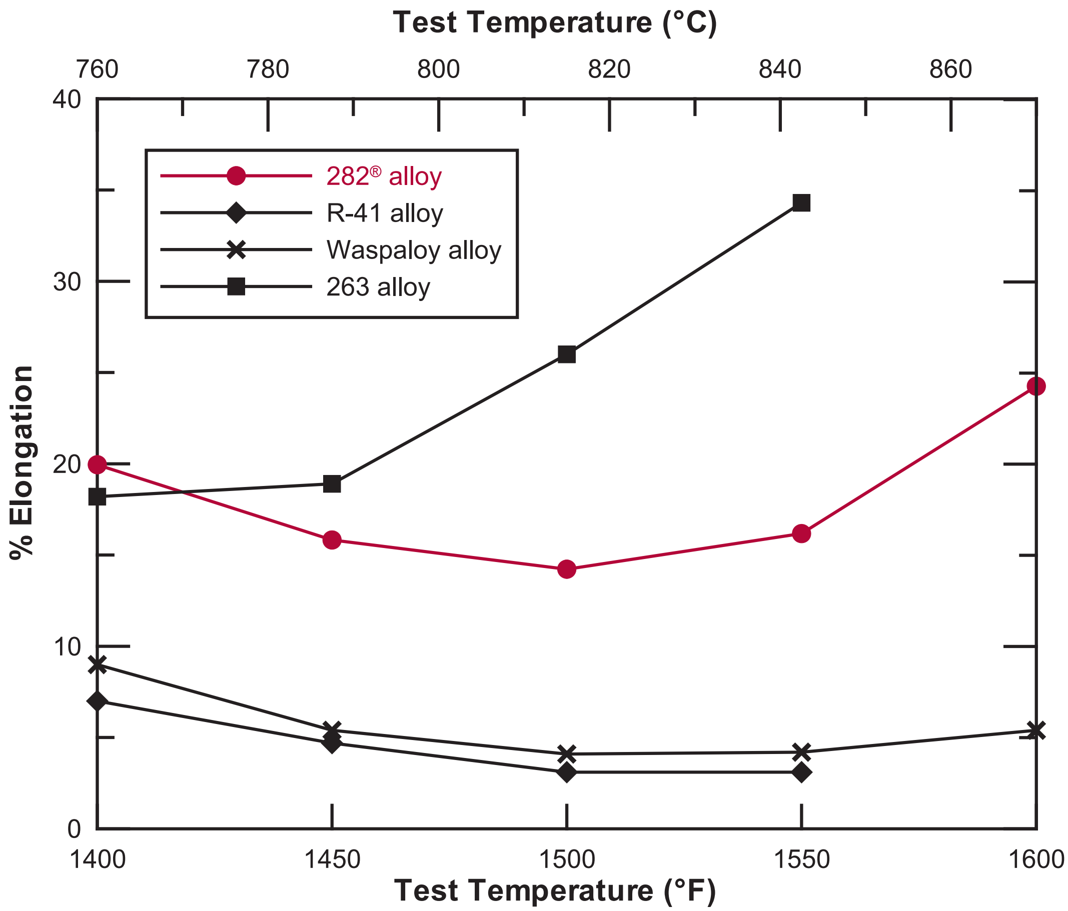
Test Temperature		Creep	Approximate Initial Stress, ksi (MPa) To Produce Specified Creep in:		
°F	°C		100 Hours	1,000 Hours	10,000 Hours
1200	649	0.5 %	—	81 (558)	—
		1 %	—	82 (565)	—
		Rupture	—	85 (586)	64 (441)
1300	704	0.5 %	73 (503)	53 (365)	—
		1 %	75 (517)	55 (379)	—
		Rupture	80 (552)	61 (421)	45 (310)
1400	760	0.5 %	49 (338)	35 (241)	—
		1 %	50 (345)	36 (248)	—
		Rupture	57 (393)	41 (283)	27 (186)
1500	816	0.5 %	32 (221)	20 (138)	—
		1 %	34 (234)	22 (152)	—
		Rupture	38 (262)	25 (172)	14 (97)
1600	871	0.5 %	18 (124)	11 (76)	—
		1 %	19 (131)	12 (83)	—
		Rupture	23 (159)	14 (97)	8 (55)
1700	927	0.5 %	9.4 (65)	4.8 (33)	—
		1 %	10 (69)	5.2 (36)	—
		Rupture	13 (90)	7.0 (48)	3.7 (26)
1800	982	0.5 %	4.2 (29)	1.8 (12)	—
		1 %	4.6 (32)	2.0 (14)	—
		Rupture	6.2 (43)	3.6 (25)	—

*2075°F (1135°C)
**1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

STRAIN-AGE CRACKING RESISTANCE

Resistance to strain-age cracking is a major attribute of HAYNES 282 alloy. As indicated in the chart below, 282 alloy approaches the well-known 263 alloy in this regard, and possesses much higher resistance to strain-age cracking than other nickel superalloys in its strength class (Waspaloy and R-41 alloys).

Resistance to Strain-Age Cracking as Measured by the Controlled Heating-Rate Tensile (CHRT) Test



The CHRT test is an excellent measure of the resistance of gamma-prime strengthened superalloys to strain-age cracking. Samples of thickness 0.063" (1.6 mm), originally in the solution annealed condition, are heated to the test temperature at a rate of 25-30°F (14-17°C) per minute, this being representative of a typical post-weld heat treatment. Tests are performed for each alloy over a range of temperatures. The susceptibility to strain-age cracking is related to the minimum tensile elongation observed within that temperature range (the higher the minimum elongation, the greater is the resistance to strain-age cracking).

For further information regarding this test, please refer to:

1. R.W. Fawley, M. Prager, J.B. Carlton, and G. Sines, *WRC Bulletin No. 150*, Welding Research Council, New York, 1970.

2. M.D. Rowe, "Ranking the Resistance of Wrought Superalloys to Strain-Age Cracking", *Welding Journal*, 85 (2), pp. 27-s to 34-s, 2006.

TENSILE PROPERTIES

Average Tensile Properties of HAYNES® 282® Alloy

Solution Annealed and Age-Hardened Sheet*

Temperature (°F)	0.2% Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	% Elongation
RT	101.4	164.2	30
1000	91.6	139.3	36
1200	91.5	146.7	27
1300	90.5	136.5	24
1400	88.7	120.8	22
1500	82.3	100.3	24
1600	72.6	80.5	31
1700	43.9	50.2	37
1800	18.7	24.5	61

Solution Annealed and Age-Hardened Plate*

Temperature (°F)	0.2% Yield Strength (ksi)	Ultimate Tensile Strength (ksi)	% Elongation	% RA
RT	103.7	166.4	30	31
1000	94.1	143.8	34	36
1200	93.2	152.0	31	31
1300	94.2	141.8	29	28
1400	91.1	124.2	22	24
1500	83.4	102.8	28	31
1600	73.6	82.1	31	42
1700	44.9	52.1	50	69
1800	19.1	25.3	71	91

Solution Annealed and Age-Hardened Sheet* – Metric Units (INTERPOLATED)

Temperature (°C)	0.2% Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	% Elongation
RT	699	1132	30
600	631	980	31
700	625	945	24
800	580	730	23
900	396	447	34
1000	75	115	64

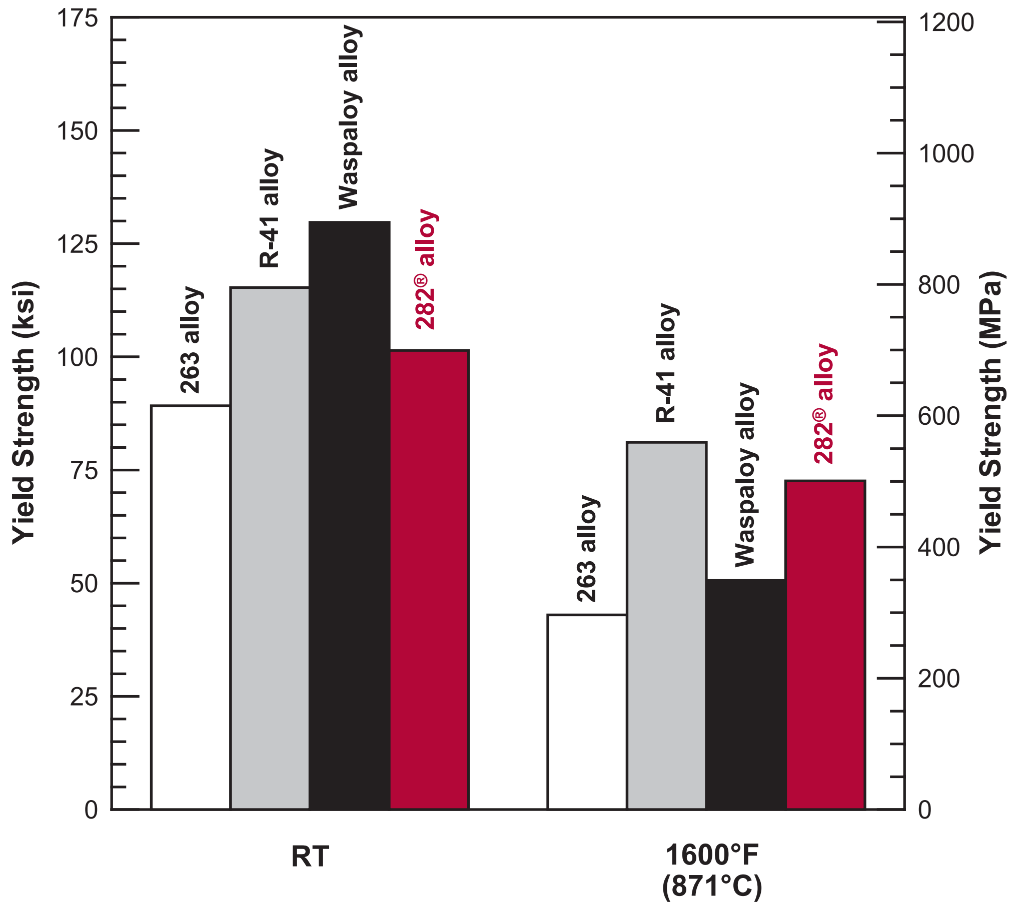
Solution Annealed and Age-Hardened Plate* – Metric Units (INTERPOLATED)

Temperature (°C)	0.2% Yield Strength (MPa)	Ultimate Tensile Strength (MPa)	% Elongation	% RA
RT	715	1147	30	31
600	645	1023	32	33
700	648	983	29	28
800	590	750	26	29
900	404	458	41	56
1000	75	115	77	98

*Solution Annealing: Sheet at 2100°F (1149°C), Plate at 2075°F (1135°C)
Age-Hardening: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

Comparative Yield Strengths of Age-Hardened* Sheet Material at Room Temperature and 1600°F (871°C)

At room temperature, HAYNES 282 alloy has a higher yield strength than 263 alloy, but is not as strong as R-41 and Waspaloy alloys, which contain higher gamma-prime phase contents. However, at higher temperatures typical of gas turbine component applications, 282 alloy exhibits excellent yield strength, surpassing that of 263 and Waspaloy, and approaching that of the less fabricable R-41 alloy.



*Age-hardened (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy : 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

HARDNESS

Average Room Temperature Hardness of HAYNES® 282® Alloy

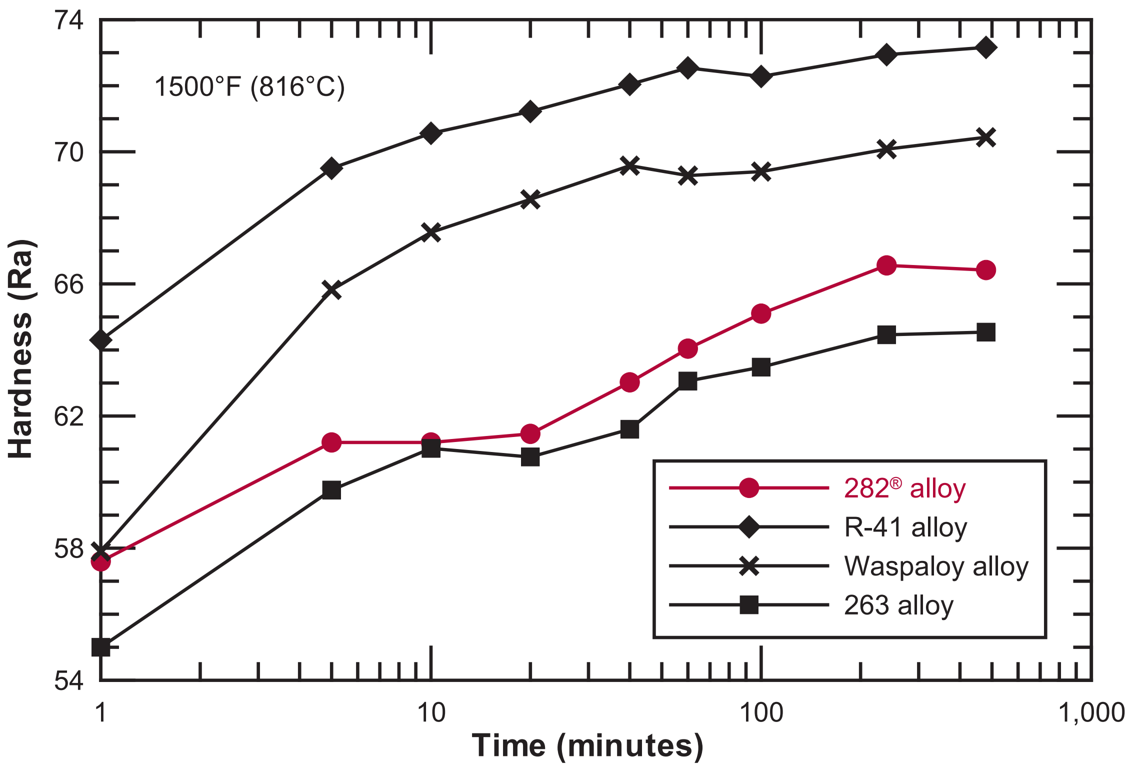
Form	Solution Annealed*	Age-Hardened**
SHEET	90 Rb	30 Rc
PLATE	93 Rb	32 Rc
BAR	86 Rb	29 Rc

*Solution Annealing: Sheet at 2100°F (1149°C), Plate and Bar at 2075°F (1135°C)
**Age-hardening: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

AGING KINETICS

A key attribute of HAYNES 282 alloy is its sluggish gamma-prime precipitation kinetics which are highly desirable for improved fabricability for two main reasons. One, the formation of gamma-prime during heat treatment is a key factor in strain age-cracking. Two, it allows sufficient time for the alloy to cool after solution annealing without formation of the gamma-prime phase which would reduce cold formability. The chart below indicates the increase in the room-temperature hardness (an indicator of the precipitation of the gamma-prime phase) with increasing aging time at 1500°F (816°C) for 282 alloy and several other gamma-prime strengthened alloys. 282 alloy was found to have a sluggish response, similar to the readily fabricable 263 alloy. The less fabricable R-41 and Waspaloy alloys hardened much more quickly.

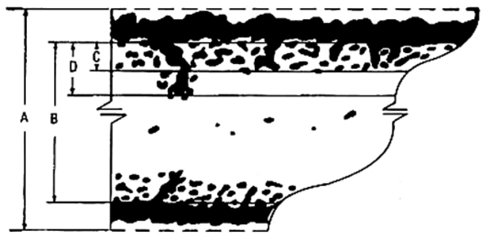
Isothermal Hardening Kinetics
Temperature: 1500°F (816°C), Starting Material: Solution Annealed Sheet



OXIDATION RESISTANCE

Static Oxidation Testing

Environment: Flowing Air
Test Duration: 1,008 h
Number of Cycles: 6
Cycle Length: 168 h
Temperatures: 1600, 1700, 1800°F (871, 927, 982°C)
Metal Loss = (A-B)/2
Average Internal Penetration = C
Maximum Internal Penetration = D
Average Metal Affected = Metal Loss + Average Internal Penetration
Maximum Metal Affected = Metal Loss + Maximum Internal Penetration



1600°F (871°C)

Alloy	Metal Loss	Average Internal Penetration	Maximum Internal Penetration	Average Metal Affected	Maximum Metal Affected
	mils (µm)	mils (µm)	mils (µm)	mils (µm)	mils (µm)
282® Alloy	0.2 (5)	0.4 (10)	1.2 (30)	0.6 (15)	1.4 (35)
R-41 Alloy	0.2 (5)	0.6 (15)	1.1 (28)	0.8 (20)	1.3 (33)
Waspaloy alloy	0.3 (8)	1.1 (28)	1.4 (36)	1.4 (36)	1.7 (44)
263 Alloy	0.1 (3)	0.3 (8)	1.7 (43)	0.4 (11)	1.8 (46)

1700°F (927°C)

Alloy	Metal Loss	Average Internal Penetration	Maximum Internal Penetration	Average Metal Affected	Maximum Metal Affected
	mils (µm)	mils (µm)	mils (µm)	mils (µm)	mils (µm)
282® Alloy	0.1 (3)	1.0 (25)	1.8 (46)	1.1 (28)	1.9 (49)
R-41 Alloy	0.2 (5)	1.3 (33)	1.6 (41)	1.5 (38)	1.8 (46)
Waspaloy alloy	0.3 (8)	3.1 (79)	3.4 (86)	3.4 (86)	3.7 (94)
263 Alloy	0.2 (5)	0.6 (15)	2.9 (74)	0.8 (20)	3.1 (79)

1800°F (982°C)

Alloy	Metal Loss	Average Internal Penetration	Maximum Internal Penetration	Average Metal Affected	Maximum Metal Affected
	mils (µm)	mils (µm)	mils (µm)	mils (µm)	mils (µm)
282® Alloy	0.2 (5)	1.6 (41)	2.1 (53)	1.8 (46)	2.3 (58)
R-41 Alloy	0.2 (5)	2.7 (69)	3.1 (79)	2.9 (74)	3.3 (84)
Waspaloy alloy	0.9 (23)	4.3 (109)	4.9 (124)	5.2 (132)	5.8 (147)
263 Alloy	1.1 (28)	3.2 (81)	4.8 (122)	4.3 (109)	5.9 (150)

Dynamic Oxidation Testing (Burner Rig)

Burner rig oxidation tests were conducted by exposing, in a rotating holder, samples 0.375 inch x 2.5 inches x thickness (9.5mm x 64mm x thickness) to the products of combustion of fuel oil (2 parts No. 1 and 1 part No. 2), burned at an air to fuel ratio of about 50:1. The gas velocity was about 0.3 mach. Samples were automatically removed from the gas stream every 30 minutes and fan cooled to less than 500°F (260°C) and then reinserted into the flame tunnel.

1600°F (871°C)/ 1,000 Hours

Alloy	Metal Loss	Average Internal Penetration	Maximum Internal Penetration	Average Metal Affected	Maximum Metal Affected
	mils (μm)	mils (μm)	mils (μm)	mils (μm)	mils (μm)
214® alloy	1.2 (30)	0 (0)	0.2 (5)	1.2 (30)	1.4 (36)
230® alloy	1.0 (25)	1.2 (30)	1.5 (38)	2.2 (56)	2.5 (64)
HR-120® alloy	1.1 (28)	1.2 (30)	1.4 (36)	2.3 (58)	2.5 (64)
263 alloy	1.4 (36)	2.6 (66)	3.0 (76)	4.0 (102)	4.4 (112)
282® alloy	1.8 (46)	2.4 (61)	2.8 (71)	4.2 (107)	4.6 (117)
Waspaloy alloy	1.8 (46)	2.5 (64)	2.8 (71)	4.3 (109)	4.6 (117)
R-41 alloy	1.2 (30)	3.1 (79)	3.7 (94)	4.3 (109)	4.9 (124)

THERMAL STABILITY

Comparative Thermal Stability Data of Gamma-Prime Strengthened Alloys (Sheet)

Room Temperature Tensile Data – Exposed* at 1200°F (649°C) for 1,000 hours

Alloy	0.2% Yield Strength*		Ultimate Tensile Strength*		Elongation*
	ksi	MPa	ksi	MPa	%
263 alloy	113.6	783	166.6	1149	21.3
282® alloy	112.9	778	172.8	1191	25.8
Waspaloy alloy	136.5	941	196.2	1353	22.6
R-41 alloy	141.9	979	189.4	1306	8.9

Room Temperature Tensile Data – Exposed* at 1400°F (760°C) for 1,000 hours

Alloy	0.2% Yield Strength*		Ultimate Tensile Strength*		Elongation*
	ksi	MPa	ksi	MPa	%
263 alloy	92.7	639	160.3	1105	32.4
282® alloy	104.1	718	170.5	1176	22.8
Waspaloy alloy	112.9	779	182.4	1258	24.0
R-41 alloy	167.0	1151	197.2	1359	1.9

Room Temperature Tensile Data – Exposed* at 1500°F (816°C) for 1,000 hours

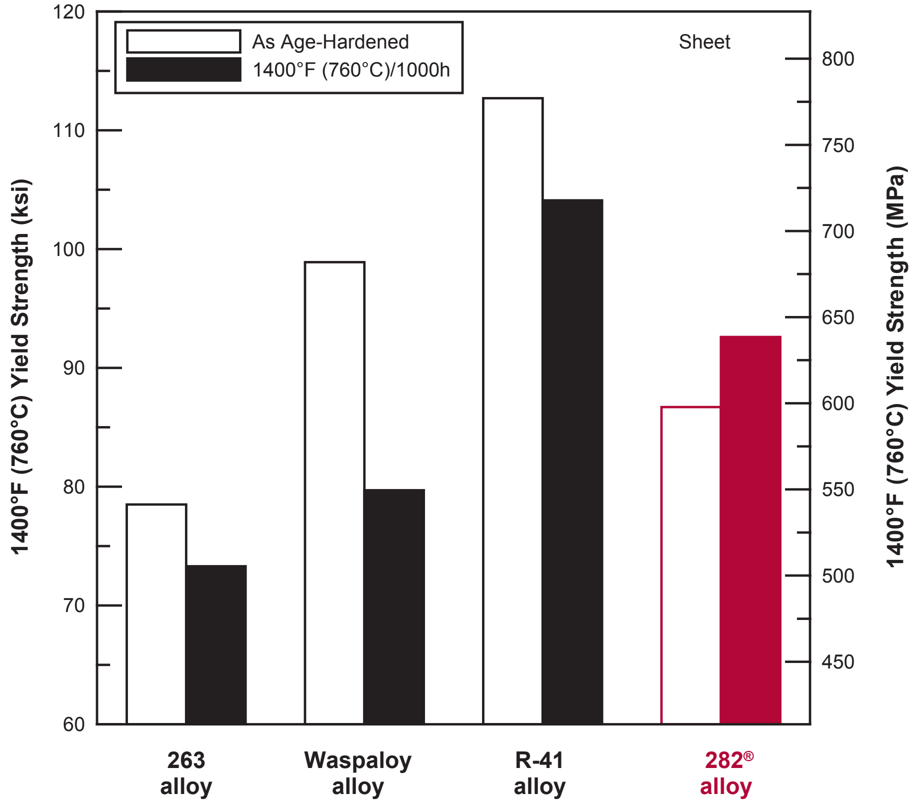
Alloy	0.2% Yield Strength*		Ultimate Tensile Strength*		Elongation*
	ksi	MPa	ksi	MPa	%
263 alloy	71.4	492	144.0	993	34.7
282® alloy	91.9	634	159.8	1102	22.3
Waspaloy alloy	103.5	714	170.1	1173	22.8
R-41 alloy	137.9	951	177.5	1224	1.8

Room Temperature Tensile Data – Exposed* at 1600°F (871°C) for 1,000 hours

Alloy	0.2% Yield Strength*		Ultimate Tensile Strength*		Elongation*
	ksi	MPa	ksi	MPa	%
263 alloy	55.0	379	125.2	863	40.9
282® alloy	72.9	502	141.4	975	24.2
Waspaloy alloy	84.6	584	149.3	1030	18.1
R-41 alloy	103.8	715	148.0	1021	2.6

*Thermal exposure was applied to samples in the age-hardened condition (263 alloy: 1472°F (800°C)/8h/AC,
Waspaloy alloy : 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC,
R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

Effect of Thermal Exposure on Yield Strength (At the Exposure Temperature)



Room Temperature Properties of HAYNES® 282® Plate after Thermal Exposure*

Exposure Temperature		Duration	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	R.A.
°F	°C	Hours	ksi	MPa	ksi	MPa	%	%
1200	**649**	0	102	705	167	1152	30	33
		100	116	798	181	1247	27	31
		1,000	118	814	181	1248	26	29
		4,000	120	830	182	1255	26	29
		8,000	119	819	183	1264	24	27
		16,000	118	816	183	1260	23	25
1400	**760**	0	102	705	167	1152	30	33
		100	110	759	177	1223	27	30
		1,000	108	742	178	1226	26	29
		4,000	103	707	175	1205	21	22
		8,000	100	690	173	1191	20	21
		16,000	96	658	168	1161	20	19
1600	**871**	0	102	705	167	1152	30	33
		100	90	618	162	1114	31	36
		1,000	77	533	155	1065	30	30
		4,000	71	487	148	1022	32	31
		8,000	69	473	146	1006	32	31
		16,000	66	452	142	978	33	32

*Thermal exposure was applied to samples in the age-hardened condition (1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

PHYSICAL PROPERTIES

Physical Properties of HAYNES® 282® Alloy* – British Units

Temperature	Specific Heat	Thermal Conductivity	Thermal Diffusivity	Electrical Resistivity	Mean Coefficient of Thermal Expansion	Dynamic Modulus of Elasticity (Young's Modulus)	Dynamic Shear Modulus	Poisson's Ratio
(°F)	(Btu/lb·°F)	(Btu·in/h·ft²·°F)	(ft²/h)	(µohm·in)	(µin/in · °F)	(msi)	(msi)	
RT	0.104	72	0.112	49.7	—	31.5	11.9	0.319
200	0.110	82	0.121	50.3	6.7	31.0	11.7	0.325
300	0.114	90	0.128	50.7	6.8	30.6	11.5	0.330
400	0.118	99	0.135	51.2	6.9	30.2	11.3	0.335
500	0.122	107	0.143	51.6	7.0	29.7	11.1	0.335
600	0.125	116	0.150	52.0	7.1	29.2	10.9	0.335
700	0.128	124	0.156	52.3	7.2	28.7	10.7	0.337
800	0.131	132	0.163	52.7	7.3	28.2	10.6	0.338
900	0.134	140	0.170	53.0	7.5	27.7	10.4	0.340
1000	0.136	148	0.176	53.5	7.5	27.2	10.1	0.342
1100	0.138	156	0.183	53.7	7.6	26.6	9.9	0.346
1200	0.140	164	0.190	53.4	7.8	26.0	9.7	0.350
1300	0.142	173	0.197	53.3	7.9	25.4	9.4	0.353
1400	0.150	177	0.192	53.1	8.1	24.7	9.1	0.355
1500	0.156	182	0.190	52.9	8.4	23.8	8.8	0.355
1600	0.158	187	0.192	52.5	8.7	22.9	8.4	0.355
1700	0.160	192	0.195	51.9	9.0	21.7	8.0	0.359
1800	0.161	199	0.200	51.3	9.3	20.6	7.6	0.363

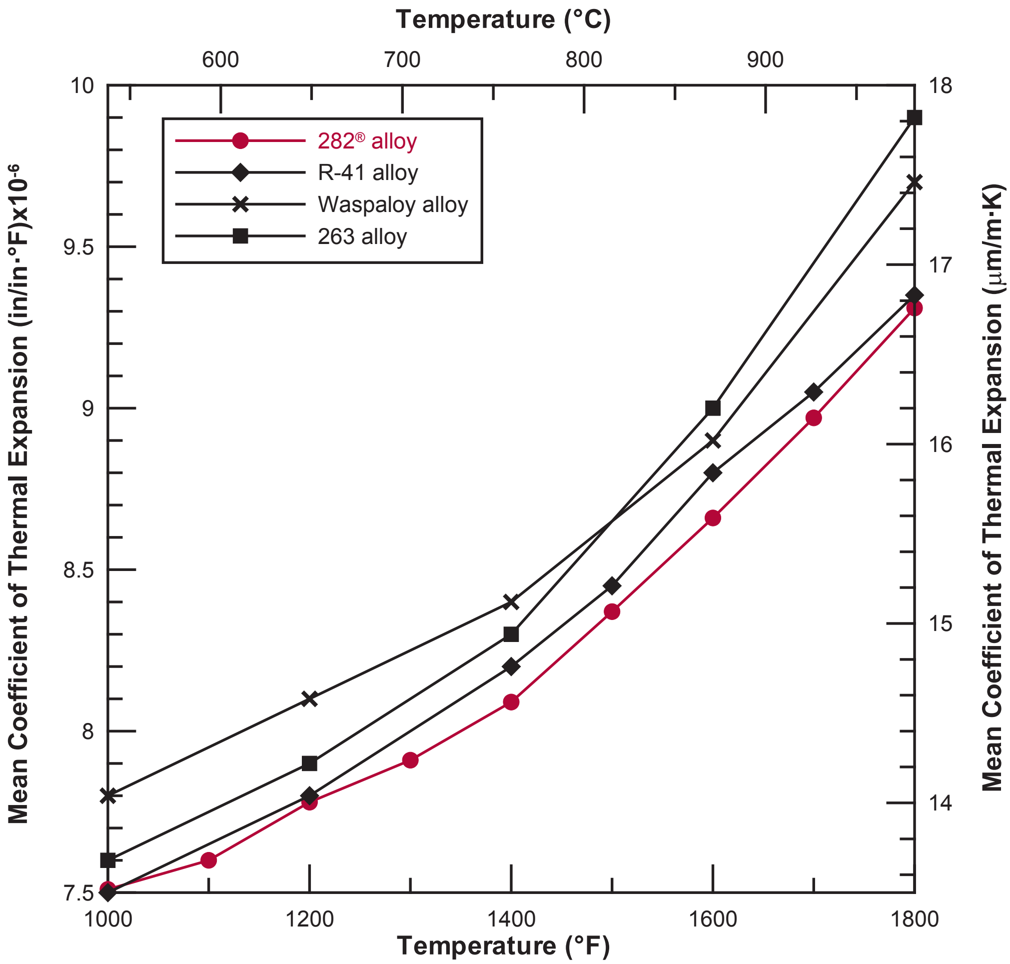
*Age-hardened 1850°F/2h/AC + 1450°F/8h/AC

Physical Properties of HAYNES® 282® Alloy* – Metric Units

Temperature	Specific Heat	Thermal Conductivity	Thermal Diffusivity	Electrical Resistivity	Mean Coefficient of Thermal Expansion	Dynamic Modulus of Elasticity (Young's Modulus)	Dynamic Shear Modulus	Poisson's Ratio
(°C)	(J/kg · K)	(W/m · K)	(cm²/s)	(µohm · cm)	(µm/m · K)	(GPa)	(GPa)	
RT	436	10.3	0.0288	126.1	—	217	82	0.319
100	463	12.0	0.0315	127.8	12.1	213	80	0.326
200	494	14.1	0.0348	129.9	12.4	209	78	0.335
300	522	16.3	0.0381	131.8	12.8	202	76	0.335
400	544	18.5	0.0413	133.4	13.1	196	73	0.337
500	563	20.5	0.0444	135.0	13.5	190	71	0.341
600	581	22.6	0.0473	136.2	13.7	183	68	0.346
700	594	24.8	0.0509	135.5	14.2	175	65	0.352
800	650	26.1	0.0488	134.5	14.9	166	61	0.355
900	668	27.3	0.0498	132.6	15.9	154	57	0.357
1000	676	28.9	0.0521	129.9	16.9	140	51	0.363

*Age-hardened at 1010°C/2h/AC + 788°C/8h/AC

Coefficient of Thermal Expansion of Gamma-Prime Strengthened Alloys* (Sheet)



*Age-hardened (263 alloy: 1472°F (800°C)/8h/AC, Waspaloy alloy: 1825°F (996°C)/2h/AC + 1550°F (843°C)/4h/AC + 1400°F (760°C)/16h/AC, R-41 alloy: 1650°F (899°C)/4h/AC, 282® alloy: 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC)

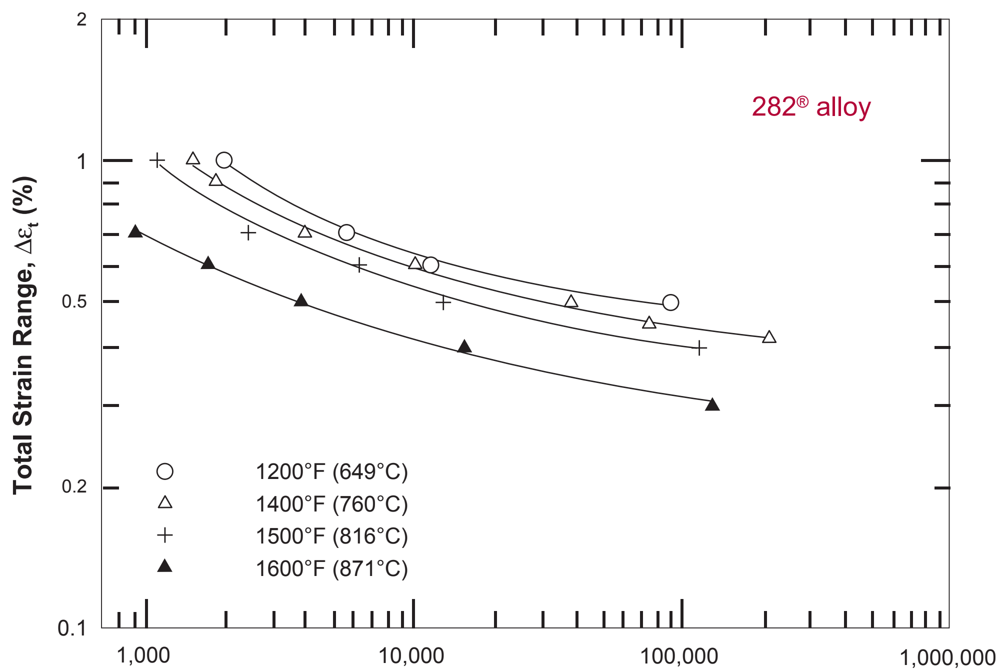
Material Properties

Density (solution annealed)	0.299 lb/in^3	8.27 g/cm^3
Density (age-hardened*)	0.300 lb/in^3	8.29 g/cm^3
Melting Range	2370-2510°F	1300-1375°C
Gamma-Prime Solvus	1827°F	997°C

*Age-hardened 1850°F (1010°C)/2h/AC + 1450°F (788°C)/8h/AC

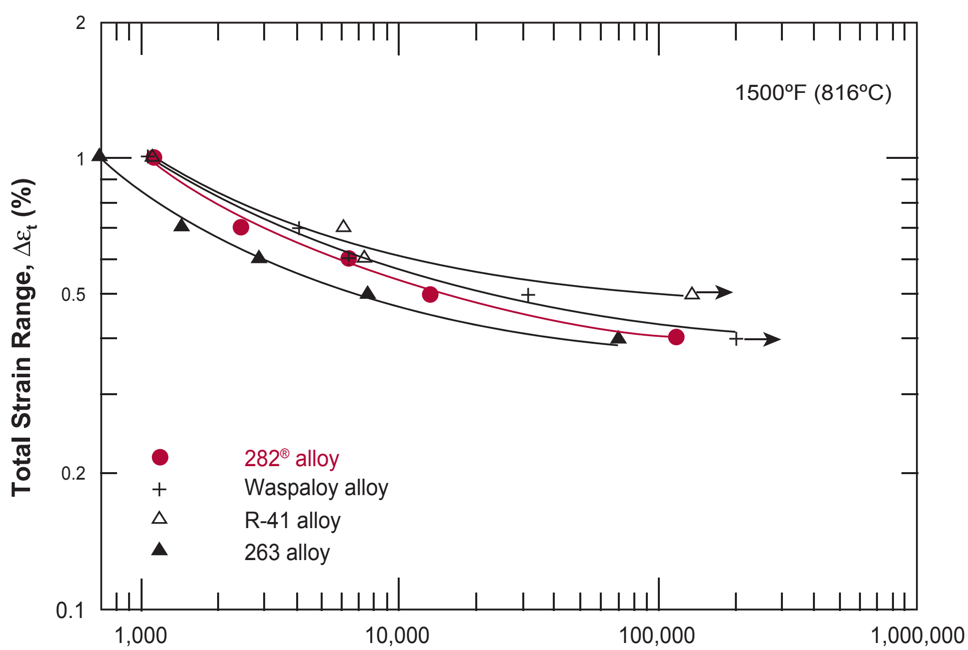
LOW-CYCLE FATIGUE

Low-Cycle Fatigue Data – HAYNES® 282® Sheet* (Thickness 0.125", 3.2 mm)



Fully Reversed, R = -1, Waveform = Triangle, Frequency = 0.33Hz

Comparative Low-Cycle Fatigue Data



1500°F (816°C), Fully Reversed, R = -1, Waveform = Triangle, Frequency = 0.33Hz, Material: 0.125"(3.2 mm) Sheet*

WELDING

As a result of its high resistance to strain-age cracking, HAYNES 282 alloy is much more weldable than other alloys of similar strength. The preferred welding processes are gas tungsten arc (GTAW or TIG) and gas metal arc (GMAW or MIG), using 282 alloy bare filler wire. If shielded metal arc welding (SMAW) of HAYNES 282 alloy is necessary, please contact the technical support group at Haynes International for information on the most appropriate coated electrode. Submerged arc welding (SAW) of HAYNES 282 alloy is not recommended due to the high heat input and increased weld restraint associated with this process.

Filler Metal Selection

It is recommended that bare, filler metal of a matching composition be used to join HAYNES 282 alloy to itself, using either the GTAW or GMAW process. HAYNES 282 alloy filler metal can also be used for dissimilar joining, and/or repair welding, of other age-hardenable, nickel superalloys.

Base Metal Preparation

HAYNES 282 alloy should be welded in the solution-annealed condition, before it is subjected to the age-hardening treatment. The joint surface and adjacent areas should be thoroughly cleaned, to reveal bright, metallic surfaces, before welding. All grease, oil, crayon marks, sulfur compounds, and other foreign matter should be removed.

Preheating, Interpass Temperatures, and Post-Weld Heat Treatment

Preheating of HAYNES 282 alloy is not required, as long as the base metal to be welded is above 32°F (0°C). Interpass temperatures should be less than 200°F (93°C). Auxiliary cooling methods may be used between weld passes, provided that these do not introduce contaminants.

After welding, HAYNES 282 alloy will normally be subjected to its age-hardening treatment, which comprises 2 hours at 1850°F (1010°C), air cool + 8 hours at 1450°F (788°C), air cool. The heat up rate to 1850°F should be as fast as possible, within the capability of the furnace being used.

The use of a full solution anneal (typically at 2075°F/1135°C) after welding and prior to the two step age-hardening treatment is neither required nor prohibited. For heavy section weldments, or complex weldments with high residual stress, a full solution anneal prior to the age-hardening treatment may be advisable.

Nominal Welding Parameters* (Sheet)

These are provided as a guide for performing typical operations and are based upon the welding conditions used in the laboratories of Haynes International. For further information, please contact the technical support group.

Manual Gas Tungsten Arc Welding

V-Groove or U-Groove – All thicknesses 0.125” (3.2 mm) or greater

Technique	Stringer Bead
Current (DCEN), amperes	150-250
Voltage, volts	11-14
Filler Metal	0.125” (3.2 mm) diameter 282® alloy
Travel Speed, in/min (mm/min)	4-6 (102-152)
Electrode Size – EWTH-2, in (mm)	0.125” (3.2 mm) diameter
Electrode Shape	30° included
Cup Size	#8 or larger
Gas Type	Argon
Shielding Gas Flow, CFH (l/min)	30-35 (14.2-16.5)
Backing Gas Flow, CFH (l/min)	10 (4.7) for root pass
Preheat	Ambient
Maximum Interpass Temperature, °F (°C)	200 (93)

Automatic Gas Tungsten Arc Welding

Square Butt Joint – No filler metal added – Material thickness 0.125” (3.2 mm)

Current (DCEN), amperes	275
Voltage, volts	9.5
Travel Speed, in/min (mm/min)	12 (305)
Electrode Size – EWTH-2, in (mm)	0.125 (3.2) diameter
Electrode Shape	45° included
Cup Size	#8
Shielding Gas Flow, CFH (l/min)	30 (14.2)
Shielding Gas Type	Argon
Backing Gas Flow, CFH (l/min)	10 (4.7)
Backing Gas Type	Argon

Gas Metal Arc Welding

Synergic Mode – All thicknesses 0.09” (2.3 mm) or greater

Wire Type	HAYNES® 282® alloy
Wire Diameter, in (mm)	0.045 (1.1)
Feed Speed, ipm (m/min)	170-190 (4.3-4.8)
Current (DCEP), amperes	175
Voltage, volts	28-32
Stickout, in (mm)	0.5-0.75 (12.7-19.1)
Travel Speed, ipm (mm/min)	9-13 (230-330)
Torch Gas Flow, CFH (l/min)	40 (18.9)
Gas Type	75% Argon + 25% Helium

Welded Transverse Tensile Data* For .125" (3.2 mm) Sheet

.125" (3.2 mm) Sheet Autogenously Welded, then with one Cover Pass
Cover Pass - .125" (3.2 mm) Diameter Wire

Temperature °F (°C)	UTS ksi (MPa)	0.2% Yield Strength ksi (MPa)	Fracture Location
As Welded			
RT	125.4 (865)	64.7 (446)	Weld/Weld
As Welded/Aged* **			
RT	168.2 (1160)	106.3 (733)	Base/Weld
As Welded/Solution Annealed**			
RT	126.8 (874)	66.9 (461)	Base/Base
As Welded/Solution Annealed/Aged*****			
RT	152.1 (1049)	98.5 (679)	Base/Base
1000 (538)	132.0 (910)	83.7 (577)	Base/Base
1200 (649)	135.1 (932)	86.1 (594)	Base/Weld
1400 (760)	120.3 (829)	83.7 (577)	Base/Base
1600 (871)	77.1 (532)	70.9 (489)	Base/Base
1800 (982)	24.7 (170)	19.1 (132)	Base/Weld

*Average of two tests ** 2075°F (1135°C)/30 min/AC ***1850°F (1010°C)/2 h/AC + 1450°F (788°C)/8 h/AC

GTAW Welded Transverse Tensile Data* For .5" (12.7 mm) Plate

0.5" (12.7 mm) Plate GTAW Welded
with .125" (3.2 mm) Diameter Wire

Temperature °F (°C)	UTS ksi (MPa)	0.2% Yield Strength ksi (MPa)	Fracture Location
As Welded			
RT	130.8 (902)	75.9 (523)	Weld/Base
As Welded/Aged* **			
RT	165.8 (1143)	120.5 (831)	Weld/Weld
As Welded/Solution Annealed**			
RT	139.5 (962)	77.2 (532)	Weld/Weld
As Welded/Solution Annealed/Aged*****			
RT	146.1 (1007)	94.3 (650)	Weld/Weld
1000 (538)	134.3 (926)	85.4 (589)	Weld/Weld
1200 (649)	137.0 (945)	86.6 (597)	Base/Base
1400 (760)	125.7 (867)	85.3 (588)	Base/Base
1600 (871)	83.4 (575)	71.9 (496)	Weld/Weld
1800 (982)	26.3 (181)	20.1 (139)	Weld/Weld

*Average of two tests ** 2075°F (1135°C)/30 min/AC ***1850°F (1010°C)/2 h/AC + 1450°F (788°C)/8 h/AC

GMAW Welded Transverse Tensile Data* For .5" (12.7 mm) Plate

0.5" (12.7 mm) Plate GMAW Welded
with 0.045" (1.1 mm) Diameter Wire

Temperature °F (°C)	UTS ksi (MPa)	0.2% Yield Strength ksi (MPa)	Fracture Location
As Welded			
RT	130.4 (899)	77.9 (537)	Base/Base
As Welded/Aged* **			
RT	162.4 (1120)	117.5 (810)	Weld/Weld
As Welded/Solution Annealed **			
RT	141.7 (977)	78.6 (542)	Base/Base
As Welded/Solution Annealed/Aged*** **			
RT	155.8 (1074)	94.4 (651)	Base/Base
1000 (538)	132.0 (910)	83.8 (578)	Weld/Weld
1200 (649)	137.3 (947)	85.2 (587)	Weld/Weld
1400 (760)	123.6 (852)	83.7 (577)	Base/Base
1600 (871)	82.0 (565)	71.0 (490)	Weld/Weld
1800 (982)	26.8 (185)	19.8 (137)	Weld/Weld

*Average of two tests ** 2075°F (1135°C)/30 min/AC ***1850°F (1010°C)/2 h/AC + 1450°F (788°C)/8 h/AC

All Weld Metal Tensile Data*

0.5" (12.7 mm) Cruciform GMAW Welded
with 0.045" (1.1 mm) Diameter Wire

Temperature °F (°C)	UTS ksi (MPa)	0.2% Yield Strength ksi (MPa)	Elongation %	R.A. %
As Welded				
RT	124.7 (860)	85.0 (586)	40.0	43.8
As Welded/Aged* **				
RT	151.6 (1045)	105.4 (727)	20.3	22.4
As Welded/Solution Annealed **				
RT	132.4 (913)	81.2 (560)	40.1	45.5
As Welded/Solution Annealed/Aged*** **				
RT	149.3 (1029)	100.9 (696)	22.7	20.0

*Average of two tests ** 2075°F (1135°C)/30 min/AC ***1850°F (1010°C)/2 h/AC + 1450°F (788°C)/8 h/AC

Comparative Creep-Rupture Properties of Weld Metal to Base Metal

Temperature °F (°C)	Stress ksi (MPa)	Material	Time to 1% Creep Hours	Time to Rupture Hours
1400 (760)	50 (345)	Base Metal*	96.8	237.5
		All Weld Metal**	197.0	364.8
1700 (927)	7 (48)	Base Metal*	335.6	792.3
		All Weld Metal**	648.0	950.5

*Annealed + Age-Hardened **GMAW Welded + Annealed + Age-Hardened

HEAT TREATMENT AND FABRICATION

Heat Treatment

Wrought HAYNES 282 alloy is furnished in the solution annealed condition unless otherwise specified. After component fabrication, the alloy would normally again be solution annealed at 2050 to 2100°F (1121 to 1149°C) for a time commensurate with section thickness and rapidly cooled or water-quenched for optimal properties. Following solution annealing, the alloy is given a two-step age-hardening treatment to optimize the microstructure and induce age-hardening. The first step is 1850°F (1010°C) for 2 hours followed by rapid or air cooling. The second step is 1450°F (788°C) for 8 hours followed by air cooling.

Hot and Cold Working

HAYNES 282 alloy has excellent forming characteristics. It may be hot-worked at temperatures in the range of about 1750-2150°F (955-1177°C) provided the entire piece is soaked for a time sufficient to bring it uniformly to temperature. Initial breakdown is normally performed at the higher end of the range, while finishing is usually done at the lower temperatures to afford grain refinement.

As a consequence of its good ductility, 282 alloy is also readily formed by cold-working. Intermediate annealing may be performed at 2050 to 2100°F (1121 to 1149°C) for a time commensurate with section thickness and rapidly cooled or water-quenched, to ensure maximum formability. All hot- or cold-worked parts should normally be annealed prior to age-hardening (as described in the “Heat Treatment” section) in order to develop the best balance of properties.

Cold Forming Characteristics

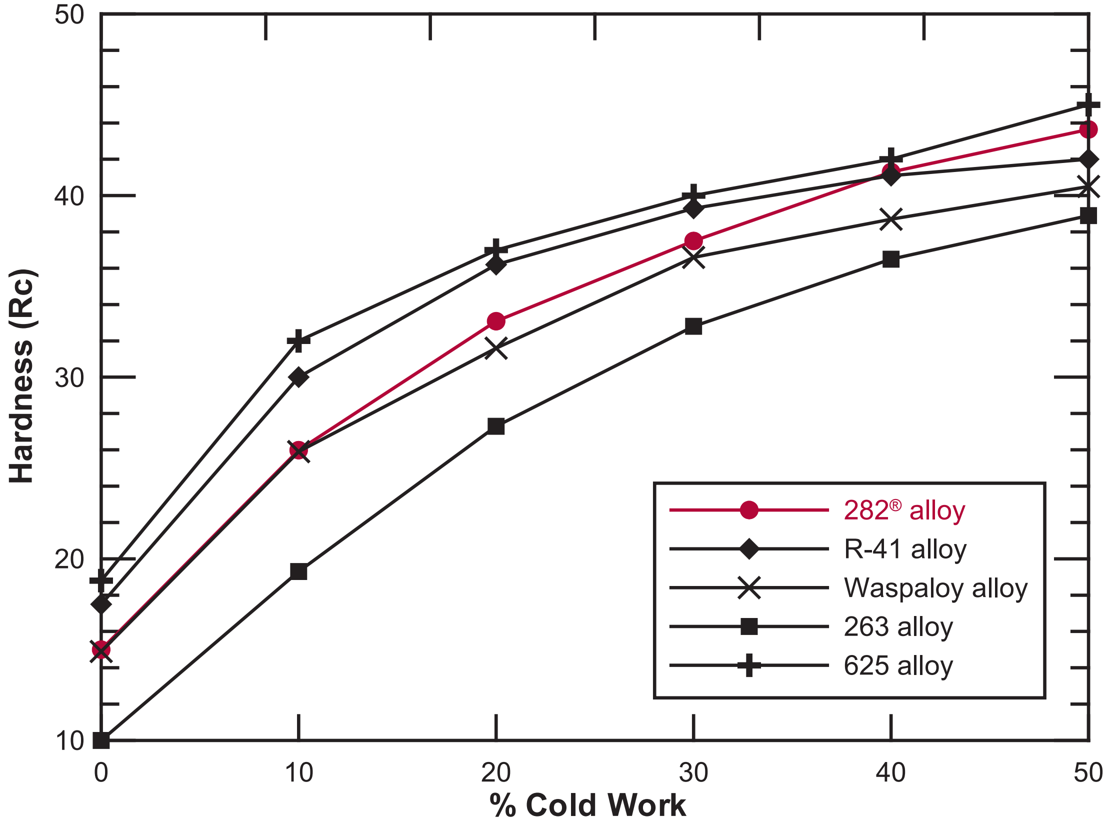
Average Room-Temperature Hardness and Tensile Properties of Solution Annealed HAYNES® 282® alloy

Form	Hardness	0.2% Yield Strength		Ultimate Tensile Strength		Elongation	R.A.
	Rb	ksi	MPa	ksi	MPa	%	%
Sheet	90	56	384	122	839	59	-
Plate	93	56	384	120	830	60	61
Bar	86	51	348	118	816	62	69

Hardness vs. Cold Work (Sheet)

Alloy	0%	10%	20%	30%	40%	50%
282® alloy	93 Rb	26 Rc	33 Rc	38 Rc	41 Rc	43 Rc
R-41 alloy	96 Rb	30 Rc	36 Rc	39 Rc	41 Rc	42 Rc
Waspaloy alloy	94 Rb	26 Rc	32 Rc	37 Rc	39 Rc	41 Rc
263 alloy	89 Rb	19 Rc	27 Rc	33 Rc	37 Rc	39 Rc
625 alloy	97 Rb	32 Rc	37 Rc	40 Rc	42 Rc	45 Rc

Hardness of Solution Annnealed Sheet Versus % Cold Work



Effect of Cold Reduction on Room-Temperature Tensile Properties*

Cold Reduction	0.2% Yield Strength		Ultimate Tensile Strength		Elongation
%	ksi	MPa	ksi	MPa	%
0	55.5	383	121.0	834	58.0
10	87.8	605	131.8	909	46.7
20	114.5	790	144.9	999	31.5
30	139.7	963	165.4	1141	15.5
40	158.5	1093	184.2	1270	8.9
50	174.7	1204	200.4	1382	6.6
60	190.4	1312	215.4	1485	5.6

*Based upon rolling reductions taken upon a solution annealed 0.125” (3.2 mm) thick sheet

MACHINING

HAYNES 282 alloy has similar machining characteristics to other nickel alloys used at high temperatures. Rough machining should be carried out prior to age-hardening, using the following guidelines. Final machining or finish grinding may be done after age-hardening. If further information is required, please contact the technical support group at Haynes International.

Normal Roughing (Turning/Facing)

Use carbide C-2/C-3 grade tool
Speed: 90 surface feet/minute
Feed: 0.010"/revolution
Depth of Cut: 0.150"
Lubricant: Dry[2], oil[3] or water-base[4,5]
Negative rake square insert, 45° SCEA[1] 0.03125" nose radius.
Tool holder: 5° negative back and side rakes.

Finishing (Turning/Facing)

Use carbide C-2/C-3 grade tool
Speed: 95-110 surface feet/minute
Feed: 0.005-0.007"/revolution
Depth of Cut: 0.040"
Lubricant: Dry or water-base
Positive rake square insert, if possible, 45° SCEA, 0.03125" nose radius.
Tool holder: 5° positive back and side rakes.

Drilling

Use high speed steel M-33/M-40 series[6]/or T-15 grades*
Speed: 10-15 surface feet/minute (200 RPM maximum for 0.25" diameter or smaller)
Feed (per revolution): 0.001" rev. 0.125" dia.
0.002" rev. 0.25" dia.
0.003" rev. 0.5" dia.
0.005" rev. 0.75" dia.
0.007" rev. 1" dia.

Lubricant: Oil or water-base. Use coolant feed drills if possible.
Short, heavy-web drills with 135° crank shaft point. Thinning of web at point may reduce thrust.

* Carbide drills not recommended, but may be used in some set-ups. See Haynes International publication H-3159 for details.

Notes:

1. SCEA-Side cutting edge angle, or lead angle of the tool.
2. At any point where dry cutting is recommended, an air jet directed on the tool may provide substantial tool life increases. A water-base coolant mist may also be effective.
3. Oil coolant should be a premium quality, sulfochlorinated oil with extreme pressure additives. A viscosity at 100°F from 50 to 125 SSU is standard.
4. Water-based coolant should be a 15:1 mix of water with either a premium quality, sulfochlorintated water soluble oil or a chemical emulsion with extreme pressure additives.
5. Water-based coolants may cause chipping or rapid failure of carbide tools in interrupted cuts.
6. M-40 series High Speed Steels include M-41 through M-46 at time of writing. Others may be added, and should be equally suitable.

HEALTH AND SAFETY

Welding can be a safe occupation. Those in the welding industry, however, should be aware of the potential hazards associated with welding fumes, gases, radiation, electric shock, heat, eye injuries, burns, etc. Also, local, municipal, state, and federal regulations (such as those issued by OSHA) relative to welding and cutting processes should be considered. Nickel-, cobalt-, and iron-base alloy products may contain, in varying concentration, the following elemental constituents: aluminum, cobalt, chromium, copper, iron, manganese, molybdenum, nickel and tungsten. For specific concentrations of these and other elements present, refer to the Material Safety Data Sheets (MSDS) available from Haynes International, Inc. Inhalation of metal dust or fumes generated from welding, cutting, grinding, melting, or dross handling of these alloys may cause adverse health effects such as reduced lung function, nasal and mucous membrane irritation. Exposure to dust or fumes which may be generated in working with these alloys may also cause eye irritation, skin rash and effects on other organ systems.

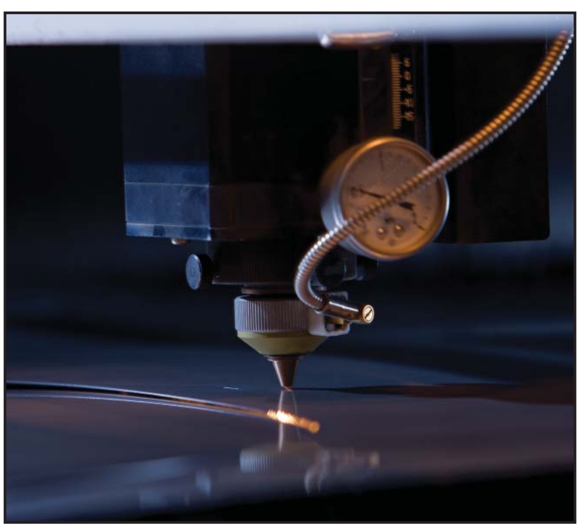
The operation and maintenance of welding and cutting equipment should conform to the provision of American National Standard ANSI/AWS Z49.1, "Safety in Welding and Cutting". Attention is especially called to Section 4 (Protection of Personnel) and 5 (Health Protection and Ventilation) of ANSI/AWS Z49.1. Mechanical ventilation is advisable and, under certain conditions such as a very confined space, is necessary during welding or cutting operations, or both, to prevent possible exposure to hazardous fumes, gases, or dust that may occur.

SERVICE CENTER INFORMATION

Service and Availability are Standard at Haynes International.

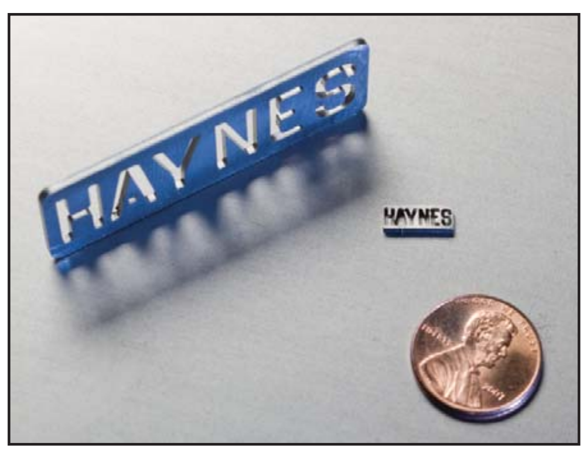
Our global service centers stock millions of pounds of high-performance corrosion-resistant and high-temperature alloys. Whether you need on-demand delivery of finished goods, end-use technical support or a partner with global presence, Haynes International provides value far beyond the alloys themselves.

Corrosion-resistant and high-temperature alloy plate is stocked in several of our global service centers and ready for immediate delivery.



Our state-of-the art laser is one of many of our specialized equipment that provides precision detail.

Our LaserQC® equipment accurately maps out parts for duplication.



Value-added services such as near-net shaped and laser-cut parts can be cut in various sizes to specific drawings and specifications to reduce your labor time and material waste.

STANDARD PRODUCTS
By Brand or Alloy Designation:

HAYNES International

HASTELLOY® Corrosion-Resistant Alloys

B-3®, C-4, C-22®, C-22HS®, C-276, C-2000®, G-30®, G-35®, G-50®, HYBRID-BC1™, and N

HASTELLOY® High-Temperature Alloys

S, W, and X

HAYNES® High-Temperature Alloys

25, R-41, 75, HR-120®, HR-160®, HR-224™, 188, 214®, 230®, 230-W®, 242®, 263, 282®, 556®, 617, 625, 625SQ®, 718, X-750, MULTIMET®, NS-163™, and Waspaloy

Corrosion-Wear Resistant Alloy

ULTIMET®

Wear-Resistant Alloy

6B

HAYNES® Titanium Alloy Tubular

Ti-3Al-2.5V

Standard Forms: Bar, Billet, Plate, Sheet, Strip, Coils, Seamless or Welded Pipe & Tubing, Pipe Fittings, Flanges, Fittings, Welding Wire, and Coated Electrodes

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